



Mitigating Impacts of Terrestrial Invasive Species

Kathleen A. Fagerstone

U.S.D.A. National Wildlife Research Center,
Fort Collins, Colorado, U.S.A.

INTRODUCTION

Human beings have introduced other species around the world both accidentally and intentionally. Accidental introductions resulted from escape from captivity (monk parakeets [*Myiopsitta monachus*] in Florida), stowaways (rats [*Rattus* spp.] and house mice [*Mus musculus*] worldwide; brown treesnakes [*Boiga irregularis*] in Guam), or expansion of species' ranges. Intentional introductions occurred for various reasons including: 1) aesthetics (songbirds into Hawaii, grey squirrel [*Sciurus carolinensis*] into Europe, and European songbirds imported by British colonists into North America, Australia, and New Zealand); 2) economics (nutria [*Myocastor coypus*] introduced in the eastern U.S., and Arctic fox [*Alopex lagopus*] onto Aleutian Islands for development of fur industries); 3) recreation (pheasants [*Phasianus colchicus*] and chukar [*Alectoris chukar*] introduced as game species from Asia to North America, and red deer [*Cervus elaphus*] introduced into New Zealand); 4) food (domestic livestock worldwide, rabbits [*Oryctolagus cuniculus*] into Australia, pigs [*Sus scrofa*] into Hawaii); 5) for biological control (mongooses [*Herpestes auro-punctatus*] to control rats in Hawaii, fox [*Vulpes vulpes*] to control rabbits in Australia, and giant toad [*Bufo marinus*] to control cane beetles in Australia); or 6) releases from captive populations (bulbuls [*Pycnonotus jocosus*] in Florida and domestic ferrets [*Mustela putorius*] in California, mink [*Mustela vison*] and muskrat [*Ondatra zibethicus*] in Europe, and horse [*Equus caballus*], donkey [*Equus asinus*], and other ungulates into Australia and western North America).

The majority of biological introductions fail. Of those that succeed, only a small fraction become serious pests. Many introductions, like livestock or pheasants into the U.S., have been generally beneficial; however, some introduced species become invasive, defined as nonnative species which cause substantial economic or ecological harm. The U.S. has at least 221 nonnative terrestrial vertebrate species^[1] and New Zealand has 35 introduced birds and 33 mammals, where previously the only mammals consisted of 3 bats.^[2] About 44 mammals have been introduced into Australia, of which 27 have become established,^[3] along with 3 species of amphibians and

reptiles and numerous birds. Ten species of terrestrial mammals on the Galapagos are aliens.

CHARACTERISTICS OF INVASIVE SPECIES AND HABITATS VULNERABLE TO INVASION

Successful invading species tend to be native to extensive habitats within continents and can usually tolerate a wide variety of environmental conditions. Also, species in close association with humans (commensal), including rats, house mice, house sparrows (*Passer domesticus*), starlings (*Sturnus vulgaris*), and rock doves (*Columbia livia*), are most successful in invading other man-modified habitats.

Certain regions are most vulnerable to introduction of invasive species. For example, not all U.S. states are affected equally by invasive species. Particularly vulnerable are Hawaii and Florida, where a high percentage of terrestrial vertebrates are introduced. New Zealand, Australia, and Madagascar also have high percentages of introduced species. Several features account for the disproportionate number of introduced species in these areas.^[4,5] The primary feature is geographic isolation: Hawaii and New Zealand are island archipelagos, Florida is a peninsula bounded on three sides by water and on one side by frost zones, and Australia and Madagascar function as insular continents. A typical feature of islands and isolated areas is an impoverished native fauna relative to equal size mainland areas. Invasive species were successful on New Zealand and Hawaii because native species did not previously occupy similar niches. Australia is another example; because birds colonized across the water barrier, the native bird fauna is diverse and only two invasive bird species have spread into undisturbed habitats.^[6] In contrast, at least 12 species of mammals with no ecological counterparts in Australia have spread widely.^[3,6]

A mild climate also makes areas vulnerable to invasive species. Hawaii and Florida have large tropical or subtropical areas without freezing temperatures. The accidental escape of exotic pets like bulbuls or the introduction of tree frogs from nursery stock would be innocuous in most U.S. regions because of cold climates. In Florida and Hawaii they thrive and spread. Finally, locations vulnerable to introductions are transportation hubs. Most visitors



from Latin America, and many from other regions, enter the U.S. through Miami, and Hawaii is a center for both civilian and military traffic moving throughout the Pacific.

ECONOMICAL AND ECOLOGICAL IMPACTS OF INVASIVE SPECIES

Pimentel et al.^[7] estimated that about 50,000 introduced species now inhabit the U.S. Not all have negative consequences, as they account for over 98% of the U.S. food system^[7] valued at \$800 billion per year. However, many nonindigenous species cause environmental damage and economic losses. In the United States, the annual cost of invasive species (including plants and aquatic organisms) is estimated at more than \$138 billion.^[7]

About 20 species of mammals have become established in the United States, including dogs (*Canis familiaris*), cats (*Felis catus*), cattle (*Bos taurus*), sheep (*Ovis aries*), horses, burros, pigs, goats [*Capra hircus*], and deer (*Cervus* spp.). Horses and burros introduced into western states number over 50,000 animals, which overgraze vegetation and decrease food for native animals. The Bureau of Land Management spends about \$22 million annually to manage these animals. Feral pigs cause damages nationwide of about \$800 million/year.^[7] Feral dogs cause about \$9–10 million in losses to cattle and sheep each year^[1,7] and feral cats kill about 465 million birds per year at an estimated cost of \$14 billion.^[7] Invasive mammals cause large agricultural losses. Nutria are pests in 15 states, causing over \$6 million per year^[1] in damage to sugarcane. Rat destruction of stored grains in the U.S. averages more than \$19 billion per year.^[7] Worldwide, rats are serious pests at farms, industrial sites, and homes. New Zealand spends over \$30 million annually controlling brushtail possums (*Trichosurus vulpecula*), which degrade native forests and spread tuberculosis,^[2] and \$2 million annually on feral goat control; cost figures do not include damage to forests and endangered species or reduced trade because of disease. About 97 of 1000 bird species in the U.S. are non-native; 5% of these, including chickens (*Gallus domesticus*), are considered beneficial while 56% are considered pests. Hawaii alone has 35 introduced species. The pigeon is the most serious pest bird in the U.S., with yearly damages estimated^[7] at \$1.1 billion to property and agricultural crops; pigeons can also spread over 50 human and livestock diseases.^[8] House sparrows, introduced into the U.S. to control canker worms, are now pests because they consume agricultural crops and ornamentals, displace native birds from nesting sites, and can spread 29 human and livestock diseases.^[8] European starlings are agricultural pests on grain and fruit crops, consume or contaminate livestock feed at feedlots, and are implicated in the spread of 25 diseases.^[8]

About 53 amphibian and reptile species in the U.S. are introduced, all in southern states and Hawaii.^[7] The brown tree snake was accidentally introduced on the U.S. territory of Guam after World War II with military cargo. Snake populations 30 years later reached densities of 100/ha and caused the extinction of 10 of 13 native forest birds, 2 of 3 native mammals, and 9 of 12 native lizards. Snakes also cause frequent power outages by shorting out utility lines, resulting in \$1 million damage yearly.^[7] The cost to control snakes on Guam and limit their dispersion to other parts of the Pacific is estimated at \$6 million per year.

Invasive species can change ecosystems through their effects on vegetation. Introduced rabbits now dominate Australia and large parts of New Zealand, where they degrade habitats for native species and for livestock grazing. Feral pigs introduced into U.S. states for hunting now number about 4 million and damage both crops and the environment.

Invasive species have caused the extinction or endangerment of numerous native species throughout the world. Introduced rats and other mammalian predators are the major cause (42%) of bird extinctions on islands, with 54% attributed to rats, 26% to cats and the remainder to mongooses, weasels (*Mustela nivalis*), stoats (*Mustela erminea*), and other species like goats and pigs. About 42% of the almost 1000 species listed under the U.S. Endangered Species Act are at risk because of invasive species.^[9] In other world regions, about 80% of the endangered species are threatened due to non-native species. Rats have caused numerous extinctions; on Big South Island, a predator-free New Zealand refuge, a 1964 rat irruption eliminated five bird and one bat species. The mongoose is a classic case of biological control run amok. Beginning in 1872, it was introduced into Jamaica, Puerto Rico, other West Indian Islands, and Hawaii for control of rats in sugarcane; it preyed heavily on native reptiles, amphibians, and ground nesting birds, causing extinction and endangerment of many species.

Mating or competition between introduced and native species can lead to extinctions.^[4] Mallards (*Anas platyrhynchos*) introduced to Hawaii and Florida for hunting hybridized extensively with the endangered Hawaiian duck (*Anas wyvilliana*) and the Florida mottled duck (*Anas fulvigula*), threatening their existence. In the U.S., the introduced starling and house sparrow outcompete native songbirds, leading to a long-term decline in songbird species.

Introduced species also propagate diseases. In Hawaii, introduced Asian songbirds are host to avian pox and avian malaria,^[4] which have contributed to the elimination of many native birds. Small rodents introduced worldwide act as vectors of salmonellosis, leptospirosis, plague and murine typhus. Feral pigs spread brucellosis, pseudorabies, and trichinosis and the mongoose is



Mitigating Impacts of Terrestrial Invasive Species

3

a vector for rabies and leptospirosis in Puerto Rico and other islands.^[7]

MANAGEMENT OF INVASIVE SPECIES

The best method for dealing with invasive species is to prevent introductions. Although global traffic volume increases continuously, many nations have no invasive species policies. In the U.S., no comprehensive law addresses imports of nonnative species, so regulatory agencies have often assumed a species will pose no problems unless proven otherwise.

It is more expensive to deal with introduced species once they are established than to prevent their introduction. Eradication is often the most cost-effective and ecologically sound solution, but can be difficult and sometimes controversial, and is most feasible in the early stages of invasion or on small islands. Rats have been eradicated using rodenticides on a number of areas, including the Aleutian Islands, Caribbean islands, and islands off New Zealand. Eradication of goats has been successful on 37 islands (up to 46,000 ha) throughout the world, primarily in New Zealand, Australia, and the Galapagos.

Where eradication is impossible, invasive species can often be managed to reduce their economic and/or ecological damage. Hunting can reduce the populations of feral pigs, feral goats, and Axis deer (*Axis axis*). Exclusion by fencing is successful but expensive. Trapping is used successfully to manage some invasive species. Brown treesnakes are trapped around airfields and ports on Guam to prevent their dispersal to other islands. Trapping and snaring are used to reduce pig and goat populations in Hawaii and in the Great Smoky Mountains National Park in the southeastern U.S.

Toxicants can provide a rapid initial reduction of invasive populations. Various rodenticides have been used effectively to manage rat populations throughout the world. Compound 1080 is used in Australia and New Zealand for controlling rabbit populations, in New Zealand for controlling brushtail possums, and on Aleutian and Pribilof Islands for eradicating arctic fox. A variety of toxicants have been used to control pigs, deer and goats. Acetaminophen (a human pain relief medicine) is being used to control or kill brown treesnakes on Guam,

and caffeine sprays are being developed for controlling introduced frogs on Hawaii.

Research is being conducted on reproductive controls which could eventually reduce invasive species populations. Reproductive control will be most effective in managing species like rats with high reproductive and low survival rates, and least effective for species such as deer with low reproductive and high survival rates.

REFERENCES

1. Bergman, D.; Chandler, M.; Locklear, A. The Economic Impact of Invasive Species to Wildlife Services' Cooperators. In *Human Wildlife Conflicts: Economic Considerations*, Fort Collins, CO, August 1–3, 2000; Clark, L., Hone, J., Shivik, J., VerCauteren, K., Watkins, R., Yoder, J., Eds.; Colorado State University Press: Fort Collins, CO, 2002.
2. Veitch, C.R. Management of exotic vertebrates: Some of the New Zealand experience. *Proc. Vertebr. Pest Conf.* **2000**, *19*, 154–159.
3. *Ecology of Biological Invasions*; Groves, R.H., Burdon, J.J., Eds.; Cambridge Univ. Press: Cambridge, U.K., 1986; 120–136.
4. Simberloff, D. *Impacts of Introduced Species in the United States*; <http://www.gcrl.org/CONSEQUENCES/vol2no2/article2.html> (July 1999).
5. Brown, J.H. Patterns, Modes and Extents of Invasions by Invertebrates. In *Biological Invasions: A Global Perspective*; Drake, J.A., Mooney, H.A., di Castri, F., Groves, R.H., Kruger, F.J., Rejmanek, M., Williamson, M., Eds.; Wiley: Chichester, U.K., 1989; 85–109.
6. Fox, M.D.; Adamson, D. The Ecology of Invasions. In *A Natural Legacy: Ecology in Australia*; Recher, H.F., Lunney, D., Dunn, I., Eds.; Pergamon Press: New York, 1979; 135–151.
7. Pimentel, D.; Lach, L.; Zuniga, R.; Morrison, D. Environmental and economic costs of nonindigenous species in the United States. *BioScience* **2000**, *50*, 53–65.
8. Weber, W.J. *Health Hazards from Pigeons, Starlings and English Sparrows: Diseases and Parasites Associated with Pigeons, Starlings, and English Sparrows Which Affect Domestic Animals*; Thomson Publications: Fresno, California, 1979; 1–138.
9. Nature Conservancy. *America's Least Wanted: Alien Species Invasions of U.S. Ecosystems*; The Nature Conservancy: Arlington, VA, 1996; 31 pp.